KNAPP

Details of Riveted Railroad Truss Bridges

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DETAILS

OF

RIVETED RAILROAD TRUSS BRIDGES

BY

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This is to certify that the following thesis prepared under the immediate direction of Professor F. O. Dufour, Assistant Professor of Structural Engineering, by

WILLARD ALFRED KNAPP

entitled DETAILS OF RIVETED TRUSS BRIDGES

is accepted by me as fulfilling this part of the requirements for the Degree of Bachelor of Science in Civil Engineering.

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Head of Department of Civil Engineering

CONTENTS.

Introduction.

The history of bridges extends as far back as that of the ancients whose first attempts were probably limited to the use of a single log or stone used to span a stream or ravine. Real bridge construction began with the stone arch of the Assyrians, which some historians date back as far as 4000 B. C. The Egyptians as far back as 2500 B. C. built arches without mortar.

These early people used wooden beams for roofs and bridges as they knew nothing of the truss. The modern truss may be an evolution of the arch, but more likely is a type of its own.

The king post truss was probably the origin of all modern trusses. From this truss the panel system was evolved. Up to the beginning of the 19th. century, all the early bridges were evolved from the king post truss and were built with a decided camber and a stiffening arch. Very little is now known of the stresses in such bridges, and at that time no attempt was made to determine stresses.

It was in this manner that bridge building went on blindly. If a mistake was made and a bridge fell down, another was built a little stronger. It was not until the beginning of the 19th. century that bridge design become a profession, and not until the middle of the century that it become a science.

With the rapid development of transportation facilities, engineers were awakened to the fact that stronger bridges must

be built. About 1800 Burr and Palmer built wooden truss bridges with camber. In 1820 Town introduced a lattice bridge of plank connected by pins. In 1840 William Howe patented a bridge using wooden chords and wrought iron verticals. The Pratt Truss was originated in 1844.

Up to this time all these bridges were built without any knowledge of the stresses in them. In 1847 Squire Whipple become interested and published a book on the determination of stresses. He also designed several bridges of the form known as the Whipple Truss. His treatise was the origin of the mathematical determination of bridge stresses, and he may justly be regarded as the Father of rational bridge design.

We can now see that the bridge of today has been developing since 1850. At present we have two types of truss bridges, pin connected and riveted. Much can be said of the relative merits of each.

Riveted trusses are coming more and more into favor on account of their great rigidity as compared with thr pin connected type. They are the more expensive of the two, but are likely to continue the favorite form of construction on account of their great rigidity and consequently low cost of maintenance.

It is the purpose of this thesis to present a discussion of the various details which go to make up a riveted span. For this purpose blue prints and drawings from many different bridge companies, as well as technical journals, have been studied. Where possible the economical as well as the structural side will be considered.

In discussing this subject two main lines will be followed, namely; The Sections and the Connections. On account of these being inter-related they will both be discussed under one head for each detail.

The plates used give sketches to illustrate the detail. These sketches are not drawn to scale.

The following details are discussed:

1. Stringers,
2. Floor Beams,
3. End Post,
4. Top Chord,
5. Intermediate Post,
6. Bottom Chord,
7. Diagonals,
8. Portal & Sway Bracing,
9. Lateral Systems,
10. Bearings.

Art. 1. Stringers.

In all types of bridges, whether plate girder or truss construction, the floor system is much the same. In all we find stringers, upon which the ties rest directly, placed lengthwise in the bridge. The stringers are supported at the ends by floor beams. There is not much latitude in the design of stringers. Either standard I-beams or plate girders are used. The length of

these stringers vary from a very short span up to 33 feet 3-3/4 inches. The latter is the length of the stringers in the Pennsylvania Railroad bridge over the Delaware River, and they are the longest spaned stringers in this country.

The usual arrangment of stringers is that of placing two parallel at a distance of six and one half feet centre to centre. On the Boston and Maine Railroad, four stringers are used. Two large ones are placed directly under the rails and two smaller ones are placed two and one half feet outside. The outside stringers are not stressed except as the main stringer is bent or broken. This seems to be a poor design, and uncertain. A better design would be to use twosmall I-beams of the same size, and placed side by side as Fig.3. The Northern Pacific Railroad use only two stringers. They use I-beams for short spans and standard built-up sections for long spans. Fig.1. shows the section of a stringer and also a method of fastening it to the floor beam.

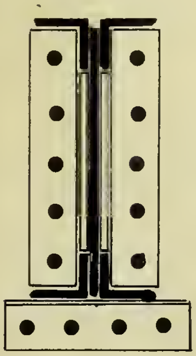
Fig.1.

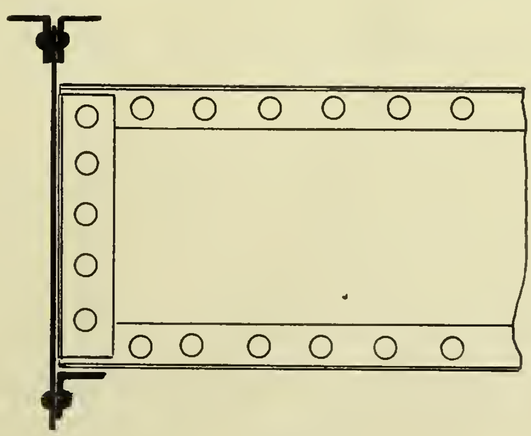
Fig.2.

This is a very common method for fastening the stringer to the floor beam and is used in both truss and plate-girder bridges. The only difference between this connection and that of the I-

beam is that no filler has to be inserted between the flange angles of the floor beam and the connection angles of the stringers.

In case the end shear of the stringer is too great to allow enough rivets to be placed in the distance of its depth, a shelf-angle is placed under the I-beam or plate girder, and this angle takes some of the shear. This shelf-angle is also used to facilitate erection, in which case stiffener angles are not required. See Fig. 2.

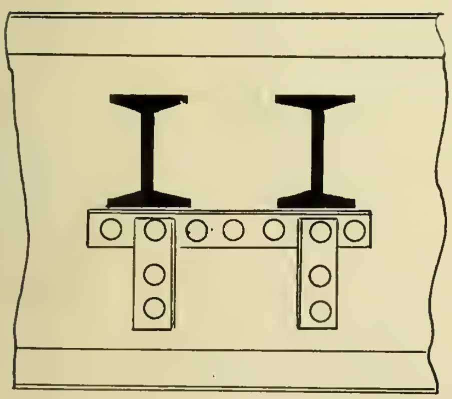

Fig.3.

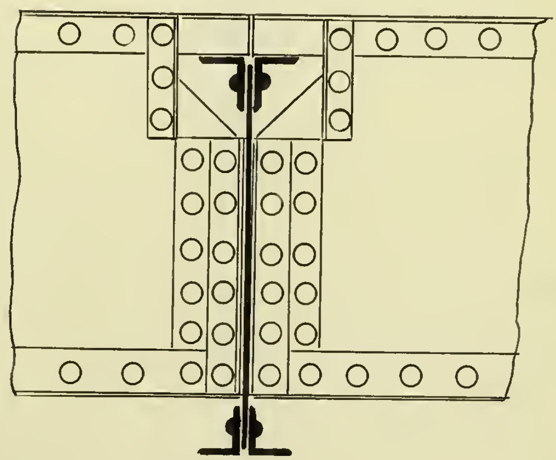

Fig.4.

In a through truss difficulties are found on account of the great spacing of the ties at the end of the stringer. A method used to avoid this and make a continuous stringer flange is to raise the stringer and allow the top flange of the stringerto pass over the flange of the floor beam. Fig. 4 shows this method.

When the stringer comes to the end of a through bridge it is often necessary to extend the stringer a foot or two past

the last last floor beam. This is necessary in order to bring the last tie on the bridge within about six inches of the first tie on the abutment. To accomplish this a bracket is built up and riveted to the floor beams. Fig. 5. shows this detail as used by some companies.

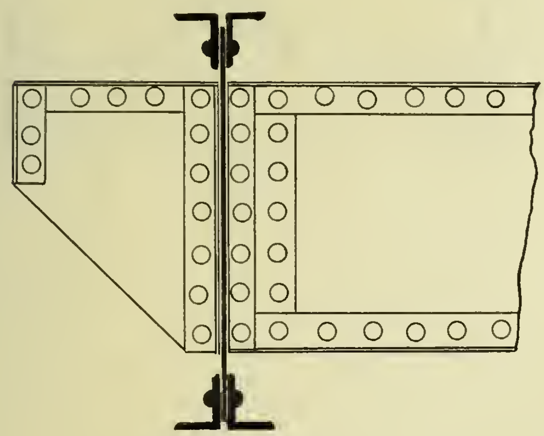

Fig.5.

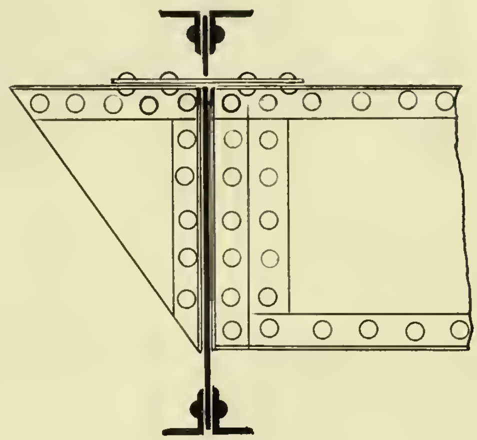

Fig.6.

There is an objection to this detail on account of the fact that a load applied near the end causes a tension in the rivets which fasten it to the floor beam. To overcome this fault the web of the floor beam is slotted and a splice plate is allowed to take the tension. Fig. 6 shows the method of making this detail.

In deck bridges the stringers are often placed on the floor beams and fastened to them by rivets through the lower flange of the stringers. When this system is used, or when the span of the stringer is very long, a system of cross bracing is used. Fig. 7 and 8 show two simple methods for bracing the two.

In the New York, New Haven & Hartford Railroad the end floor beam is sometimes omitted and the stringer rests upon the abutment. In order to bring the stringer to the right

level a detail similar to Fig. 9 is used. This is fastened to a masonry by means of bolts in slots in order to allow a lengthwise movement.

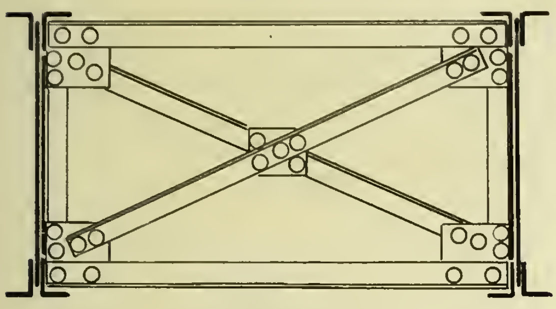

Fig.7.

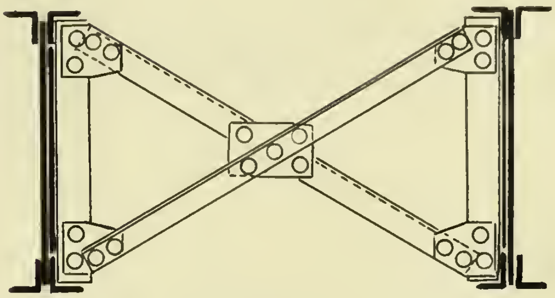

Fig.8.

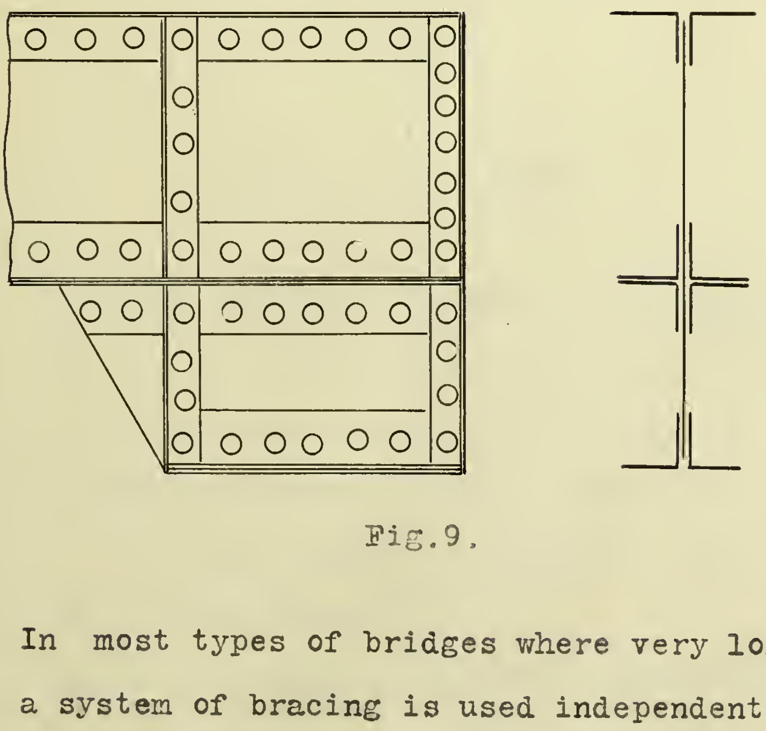

Fig.9.

In most types of bridges where very long stringers are used, a system of bracing is used independent of the bottom lateral system of the truss. The most common system is the plain Warren system shown in Fig. 10. This same system with verticals is also used in some cases, see Fig.11.

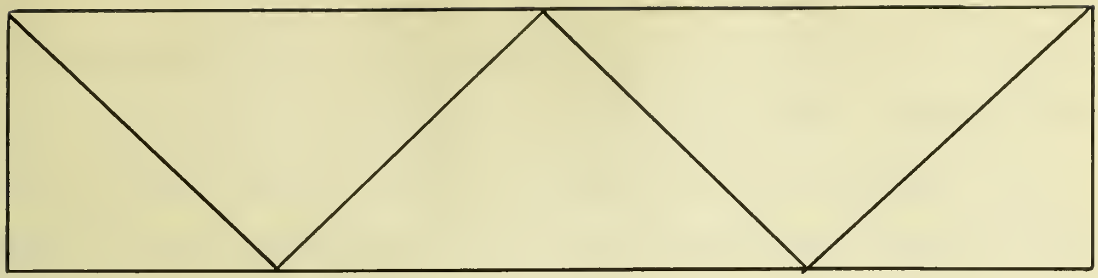

Fig.10.

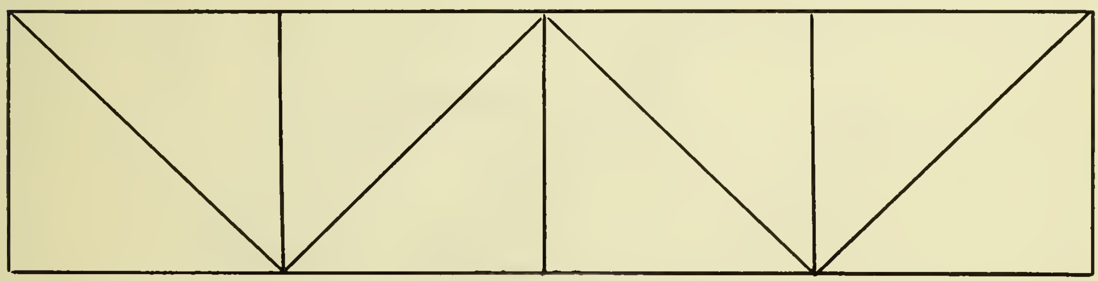

Fig.11.

Art.2. Floor Beams.

The floor beams of a bridge are placed perpendicular to the stringers and join the two trusses of the bridge at their panel points. On account of the weight which is brought on this member, only built up sections can be used; and on account of the size of these sections, some difficulty is found in fastening the floor beam to the bridge truss.

The floor beams are used throughout the length of the length of the bridge and may be divided into two general types on account of their position, namely: end-floor beams and intermediate floor-beams.

Much difficulty is found in fastening the end floor-beam, because of the inclination of the end post. Fig.12 shows a simple method of fastening the end floor-beam. This particular detail is taken from a bridge designed by the Phoenix Bridge Company. Here the weight on the end floor-beam comes directly upon the pin and bearing.

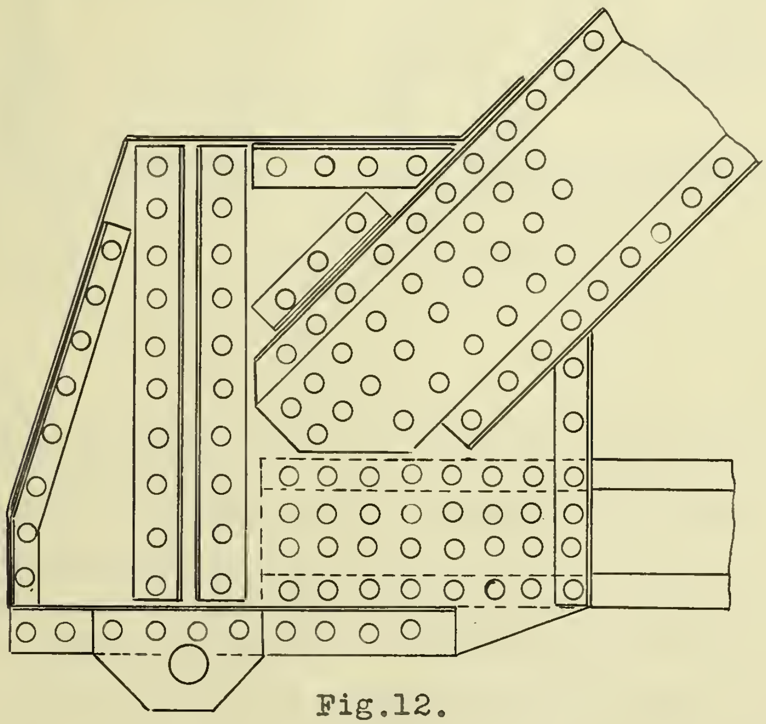

Fig.12.

The sketch shows the position of the detail and its relation to the post. The floor-beam consists of a simple built-up section without any end angles. This floor-beam is riveted into place and field riveted to the truss. One of the angles shown is to be field riveted. This makes it necessary to place a row of field rivets in the vertical and horizontal legs of the angles. In order to accomplish this the box like arrangement

is left open until the floor-beam is in place and then a metal plate is bolted to the box. The main objection to the detail is the field riveting that is required.

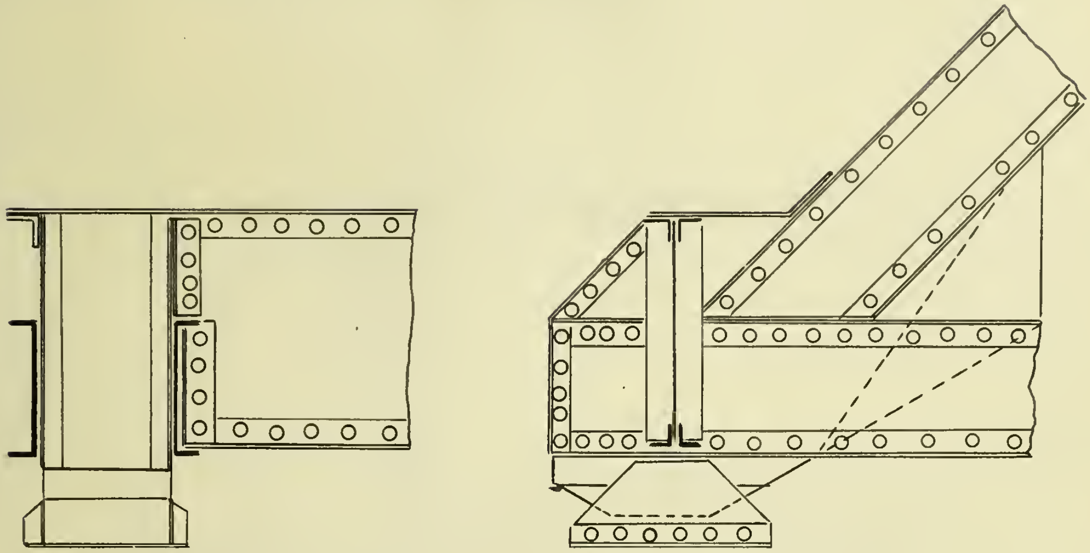

Fig.13.

The standard detail of the end floor-beam used on the New York Central and Hudson River Railroad is shown in Fig.13. On account of the projecting angles of the lower chord, it is necessary to make a notch in the floor-beam in order to extend the web below the chord. As considerable weight and shock comes on the end floor-beam, it is necessary to extend a gusset plate above the intersection of the bottom chord and end post to make a solid connectoin. No serious objection can be seen to this connection.

The American Bridge Company use a simple means of fastening the floor-beam. This consists of letting the lower flange of the floor-beam rest on the bearings and rollers. A plate is then riveted to the floor-beam and bent so as to

fasten on the cover plate of the end post in order to stiffen the floor-beam and keep it from rotating about its lower flange. This detail is shown in Fig.14.

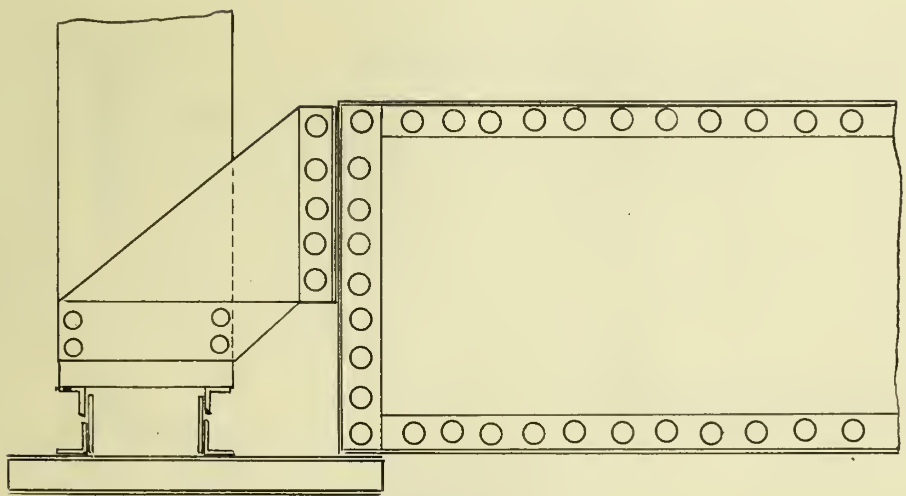

Fig.14.

There is little question but that this detail is the most favorable of end floor-beam connections on account of its ease in putting in place and the absence of many field rivets. The appearance may not be as neat as some others but is as effective and is also more economical.

A similar detail to this is where the plate is riveted to the side of the end post instead of the top. It is difficult to rivet this plate to the side on account of the flange and proximity of the floor-beam itself.

A Canadian bridge company used a detail as shown in Fig.15. The upper flange and part of the web of the floor-beam is allowed to extend over the top of the end post. The end post has flanges on either side and in order to place the

floor-beam in place a portion of each flange is removed. A plate is riveted to the end post and floor-beam to prevent a rotating about the intersection of the web and end post. All the stress is transfered through rivets to the end post.

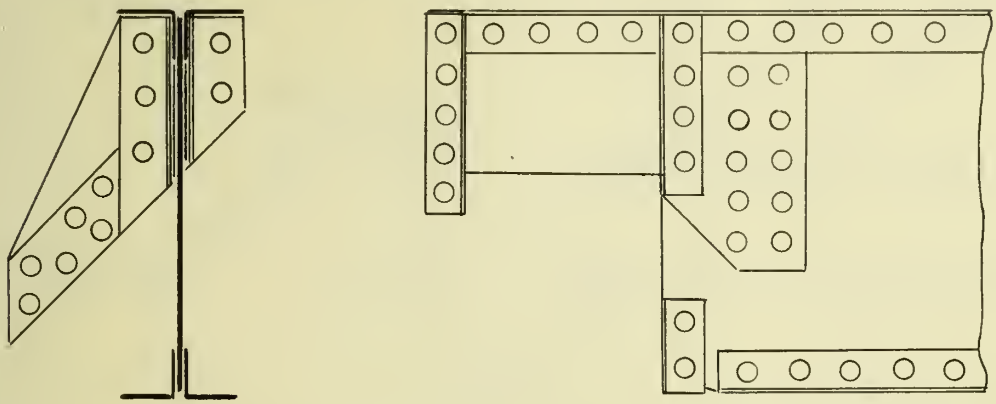

Fig.15.

The principle advantage of this method of connection is the simple method for bracing the floor-beam where it comes above the top of the end post in order to prevent the great tendency to rotate. It is difficult however to determine how the stress will act. Part of the stress is taken up on either side by rivets; but the stress that is taken up by the outside rivets is carried by the web from the inside of the end post. One reason for the lack of favor in this detail is the amount of shop work required to get it into position.

Where it is desirable to build a deep floor-beam and avoid making a jog past the lower chord, the method shown in Fig.16 is very effective, the few field rivets required being a very important point in its favor. It willalso be seen that instead of the weight being taken by a row of rivets, a bearing

surface is had on the cover plate of the end post.

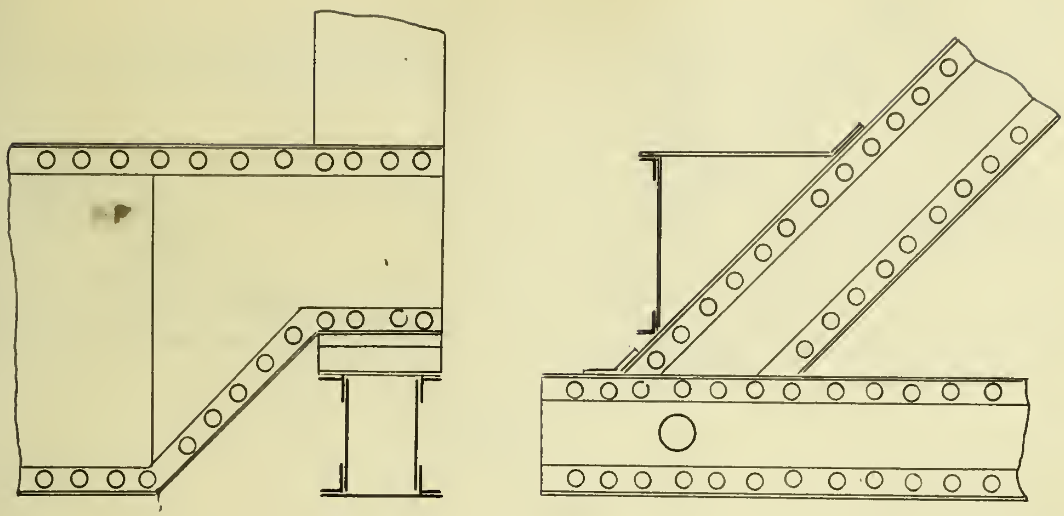

Fig.16.

The Northern Pacific Standard plans show a method much the same. Fig.17 and 18 show two details used. These differ only in the type of connection at the pedestal. In the one the lower chord extends past the pin, and in the other a separate detail is used for the pedestal.

The details shown in Fig.16,17 & 18 are all similar and have the same objections. In the first place all of them are more elaborate than common practice justifies. The designer of today should try to make a detail as simple as possible as well as neat in appearance. It is also argued that riveting of these connections to the end post have the effect of weakening the post. Not withstanding these facts some railroads have adopted these details as standards.

The American Bridge Company has a detail which is used in place of an end floor-beam. Fig.19 shows one view of

this detail and Fig.20 another.

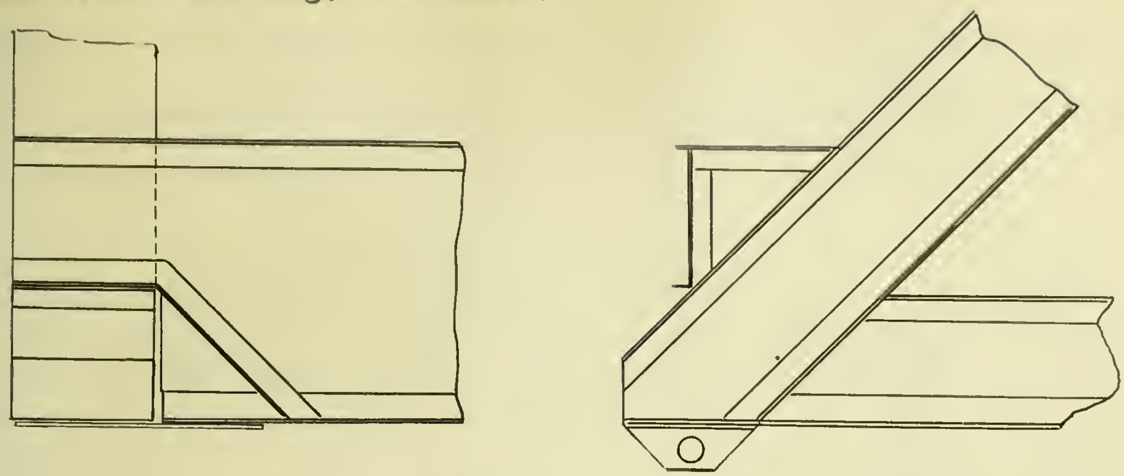

Fig.17.

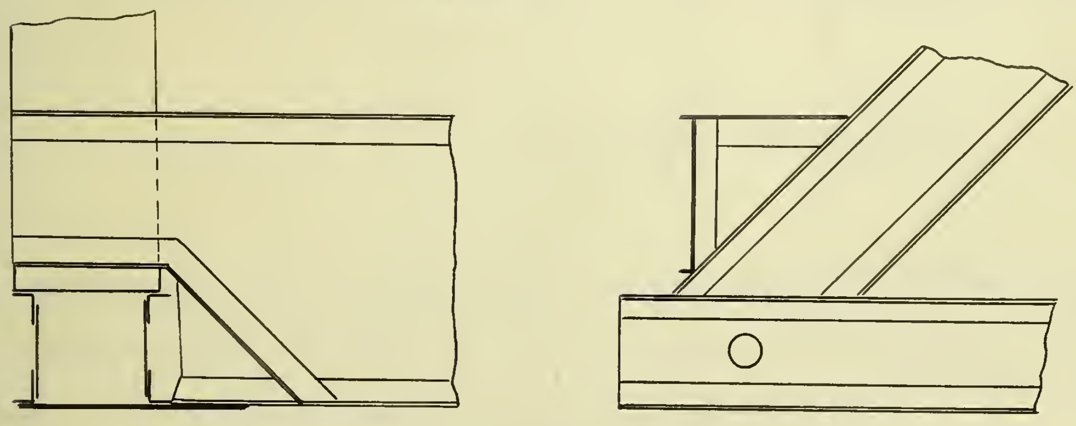

Fig.18.

In this detail, which is in reality an end strut ,the stringer to passes over. This avoids using the stringer bracket. No attempt is made to construct a rigid fastening to the end post for little weight is taken at that point. The top flange of the strut passes over the top of the end post, and is riveted to the cover plate by means of a bent plate. The only stress that is brought on this connection is weight due to the member itself and any twisting movement that occurs. The argument in favor of this detail is the ease with which the road bed and bridge can be joined on account of the stringer extending past the end of the bridge.

One drawback to this detail is the form of bridge seat that is required. In order to have a place for the bearing, it is necessary for the centre position of the bridge seat to be raised some distance.

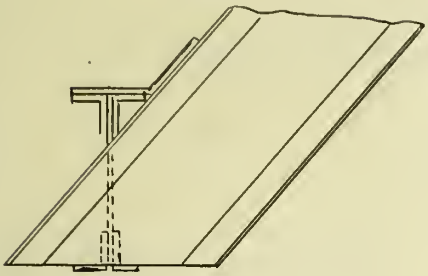

Fig.19.

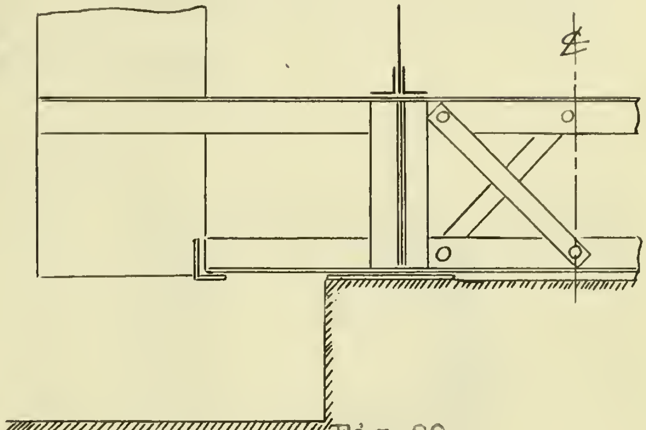

Fig.20.

At one time the end floor-beams were used only in long spans. At present they are used almost entirely, and a number of railroads have adopted them as standard construction.

Fig.21.

Perhaps a more difficult problem is the intermediate floor-beam connections. This is made difficult on account of the proximity of the lower chord.

In deck truss bridges the lower chord does not inter-

fere and a detail similar to Fig.21 will serve. This floor-beam is made up of plates and angles with stiffeners under each stringer. These stiffeners consist of four angles, two on each side placed back to back. The end angles are field riveted to the intermediate posts. All that is necessary is to have enough space for the required number of rivets.

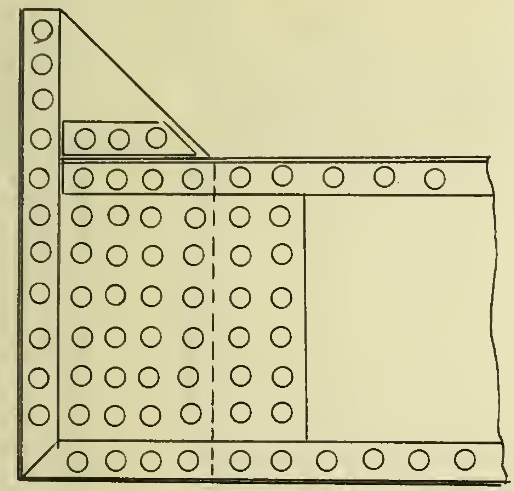

Fig.22.

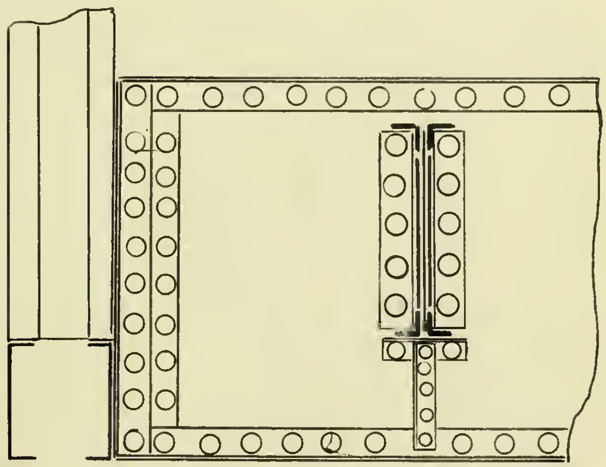

Fig.23.

It is only in the thru truss that difficulty is found in the intermediate floor-beams. Fig.22 shows the details of a floor-beam used by Boston Bridge Works. Here, the lower chord consisted of channel with the flange turned in and the inner side of the intermediate posts and lower chord were in a plane. The splice plate acts as a stiffener and adds strength to the floor-beam. In order to give ample room for riveting, the floor-beam to the intermediate post it is often necessary to extend a plate and pair of angles some distance above the floor-beam. A similar intermediate floor-beam used by the American Bridge Company is shown in Fig.23 in which no extension plate is necessary. The sketch explains itself. The only difficulty is

found in the field riveting.

Where the flange on the bottom chord extend outward it is necessary to make an offset in the end of the floor-beam similar to that shown in Fig.24.

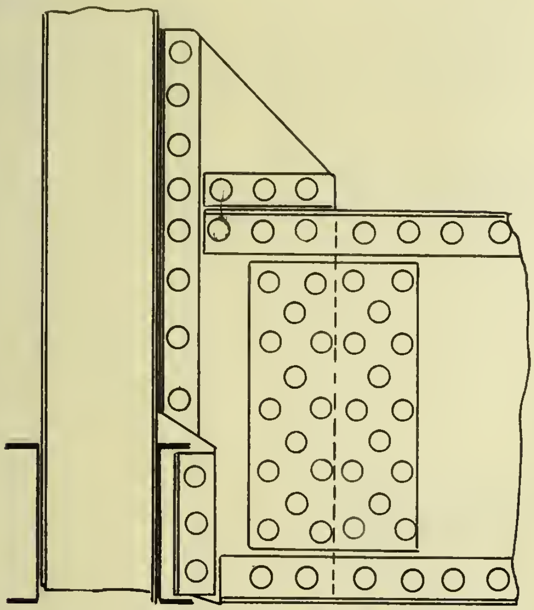

Fig.24.

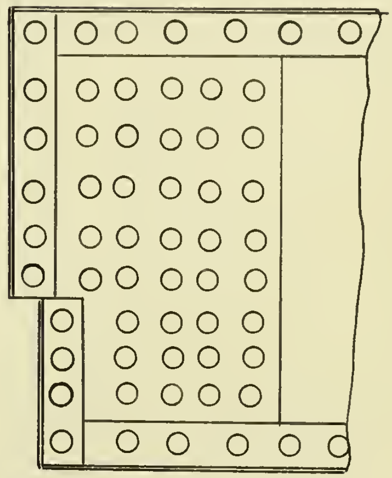

Fig.25.

This floor-beam is riveted to both the bottom chord and intermediate post. Where it is possible to make a detail like this it is a matter of economy for the lower the floor-beam is the less height is required for the head room thru the bridge. Fig.25 is a sketch of a detail used where the lower chord is a built-up box and extends out farther than the intermediate post or subvertical. Apair of angles are riveted on the upper flange to insert a triangular gusset plate to act as a brace and give more rigidity to the truss.

Occasionally it is not desirable to rivet the lower part of the floor-beam to the side of the bottom chord as this is a difficult part of the field riveting. The detail shown

in Fig.26 is used in the Port Perry Bridge over the Monongahela River. A trapizoid web plate stiffened with angles is riveted to the bottom side of the lower chord. This construction has the effect of causing a negative moment which reduces the positive bending moment due to the load. The same thing is true of the detail shown in Fig.27 and 28.

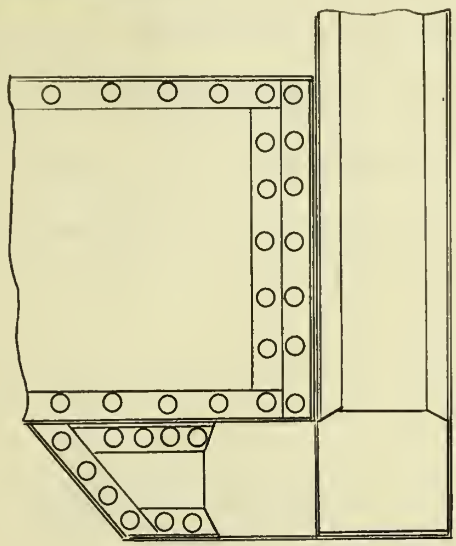

Fig.26.

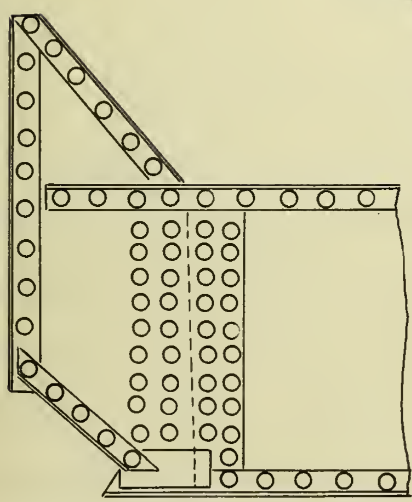

Fig.27.

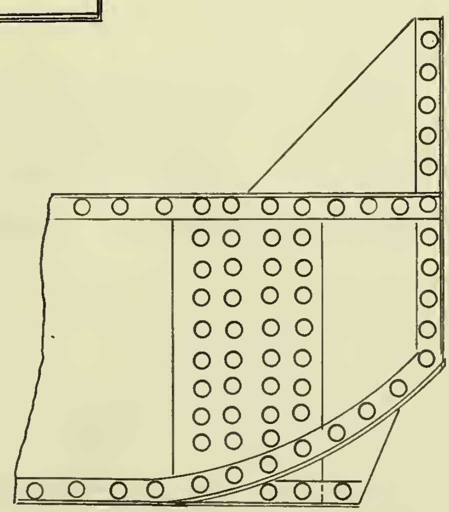

Fig.28.

Beside the advantage had in construction, both of these details permit of close inspection of all parts as well as room to paint. The detail has no advantage over that of Fig.28 except in appearances. The curved

angle gives a pleasing appearance but makes a difficult problem of design as well as difficult shop work.

These details show the general methods used in connecting the floor-beam to the truss. In choosing a detail the first requisite is simplicity of design, both from a standpoint of economy and ease of erection. An elaborate detail would require more skill to design and construct, but the final purpose would not be served any better than by one simpler and cheaper.

As a rule simplicity and cheapness will go together. The detail that will serve the purpose and be economical is the detail to use.

Art.3. End Post.

The longest compression member of ordinary truss bridge is the end post. On account of this member always taking compression the post is designed as a column. Besides the stresses brought in post by the dead and live loads, wind loads and eccentric loads add to the direct stress. The wind on the bridge and train cause an overturning effect on the bridge. The stresses due to the wind are then a direct stress and a bending stress at the foot of the portal bracing. The eccentric stresses are caused by a tendency of the end post to bend on account of the load not being applied at the neutral axis of the section. All of these forces add to the stresses in the post, and thus requires the section to be enlarged.

Fig.29. shows the most common detail of a cross section. In this detail two channels are used with a cover plate on the upper side, and lacing on the lower to keep the channels spaced. When the cover plate alone is used the centre of gravity of section is near the plate.

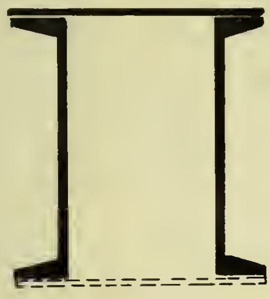

Fig.29.

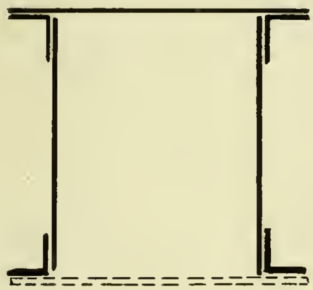

Fig.30.

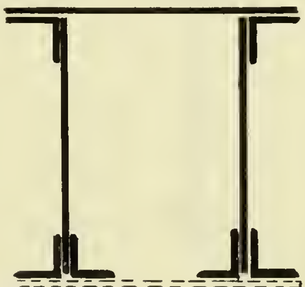

Fig.31.

In order to bring the centre of gravity nearer the ~~centre of the~~ centre of the two channels, narrow strips of steel are sometimes added to the lower flanges of the channel to balance the section. These strips are called flats. Where the required section is less than the minimum allowed, the cover plate is omitted and the post is laced on both its top and bottom sides. In this case the pin is placed in the centre of the web, and therefore no eccentricity results. Channels are used for depths of fifteen inches or less, and built up sections for depths of over fifteen inches.

Two common types of built up sections are shown in Fig.30 and 31. Fig.30 may have a flat to help balance the section, or may have lacing on both sides in case th cover plate is not required. The extra angles in Fig.31 are for the purpose of balancing the section. Sometimes it is necessary to stiffen

the post by means of a plate placed between the flange angles and riveted for the length of the post. This is shown in Fig.31.

Still another section used in riveted bridges is the one shown in Fig.32.

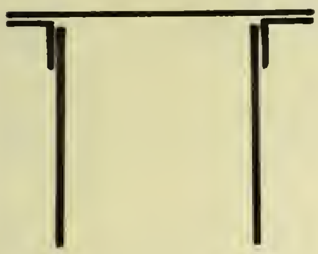

Fig.32.

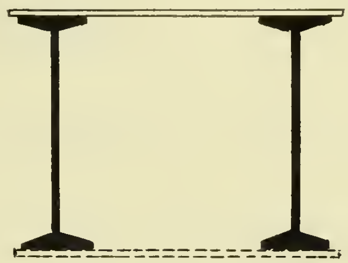

Fig.33.

This consists of two angles and three plates. The design is poor on account of the centre of gravity being far from the centre of the webs making an unsymetrical section which is to be condemned. The section is not deep but nevertheless the pin at L_0 has to be thrown off the centre of the webs in order to eliminate eccentric stresses. On account of the upper end being riveted the fact that the pin is off centre makes a difficult problem in exactly computing stresses. The lower part of the post can not be held rigid unless lacing is used. A heavy section sometimes used is shown in Fig. 33. This section is not in common use.

The method of lacing might be taken up here. There are two general kinds of lacing, namely; single and double lacing. Since the function of lacing is to keep the two sides of the post apart and cause equality of stresses in the two sides of the member the double lacing is to be prefered except in light sections.

The form of lacing shown in Fig.34 is the most common. In this the post is held solid and the stresses equally distributed between the two channels.

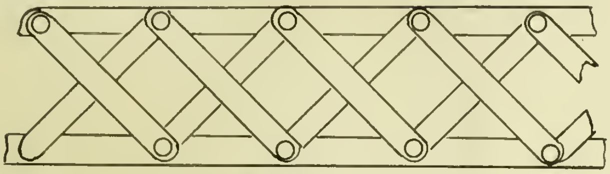

Fig.34.

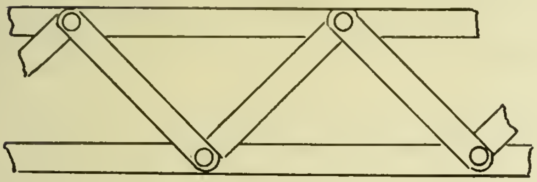

Fig.35.

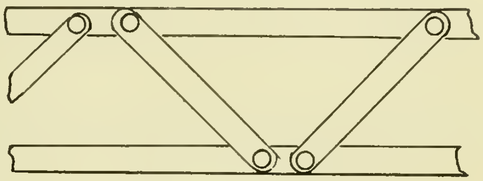

Fig.36.

There are two common forms of single lacing. These are shown in Fig.25 and 26. The first requires more lacing and unless the lattice bars are of such a thickness to make a rivet to long, this form is prefered to the second. The form of Fig.36 requires almost twice as many rivets as Fig.35 and is no more effective. In fact the appearance is not as desirable.

For medium length bridges, posts with sections such as are shown in Fig.29 and 30 are the best and the lacing of Fig.35 is prefered.

Two details of heavy end post sections are shown in Fig.37. These post sections are only economical in very large bridges, on account of the difficulty found in riveting the inside members.

There are three general methods of fastening the end post to the lower chord, vis., where the end post is placed out side of the lower chord and is riveted directly to it; or

where the lower chord is outside and the end post is riveted on the inside; or both are riveted to a gusset plate.

Fig.37.

The first two methods are objectionable on account of the additional details required at the top of the pedestal. The latter detail is a stronger and simpler detail and makes a more rigid connection.

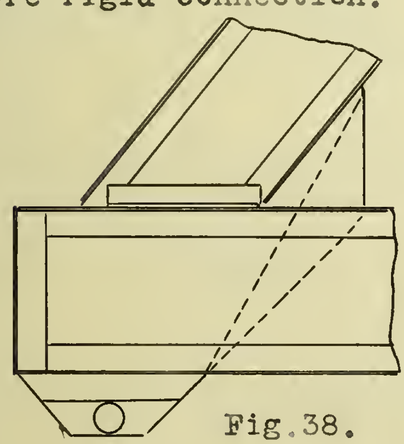

Fig.38.

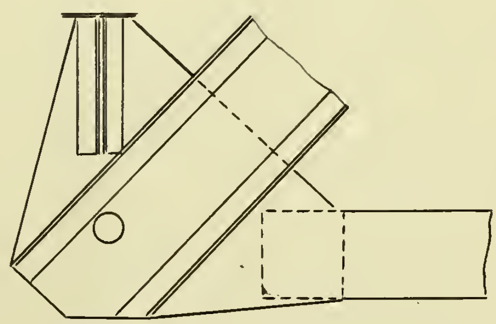

Fig.39.

A method where the gusset plate is used is shown in Fig. 38. The bottom chord and end post are the same width and are connected by means of two plates riveted inside of the members. This detail is neat and economical. One feature to be noted is the extension of the two plates below the lower chord. This extension provides a connection to the pedestal, thus making the end post and lower chord fasten directly and rigidly to the pedestal. The end post is field riveted to the plate. This detail is good.

Another riveted plate connection is shown in Fig.39. This detail was designed for the Vera Cruz and Pacific Railway in Mexico. There may have been some object in view for this design but it seems to be a poor one. One objection is the position of the pin. In place of lacing in this bridge plates 2-1/2" by 7/16" were riveted at intervals along the lower side of the end post. This design is simple but the appearance is anything but pleasing.

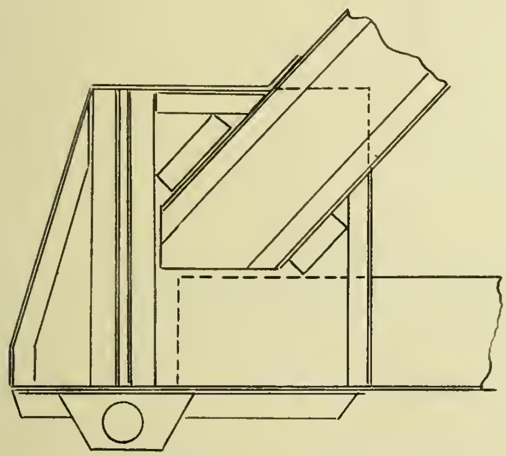

Fig.40.

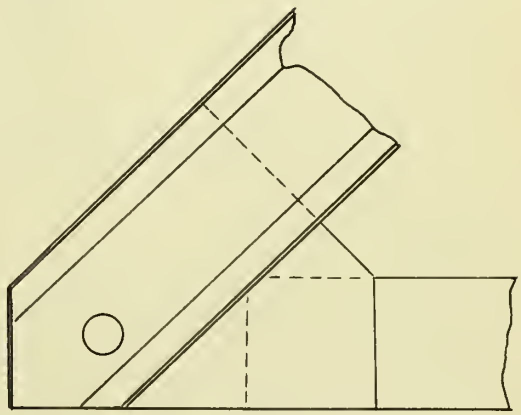

Fig.41.

The Phoenix Bridge Company have designed a detail for the connection of the end post to bottom chord. Fig.40 shows this. The construction of this detail is simple enough. The two plates which hold the end post and the top chord together also support the end floor-beam. A serious objection to the design is found in the fact that the pin is not in a line with the centre of gravity of the end post. As far as the construction is concerned this detail is good and makes a satisfactory connection.

Fig.41 illustrates another neat detail employing a gusset plate. This detail is good in that the pin is in line

with the centre of end post and bottom chord, and no bending moment can result in the connection. This detail is neat and evolves no difficulty of erection or design. The only draw back to this is the high pedestal that is required.

Fig.42 shows a detail by a Montreal Bridge Company and was designed for the Canadian Pacific Railroad. The peculiarity

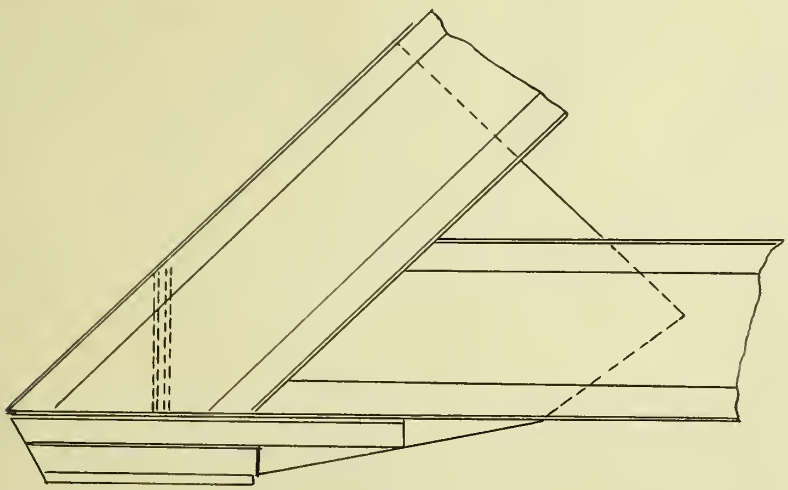

Fig.42.

in this design is the pedestal which consists of a disk. A plate is riveted to the bottom of the connection and a diaphragm riveted in the position shown by the dotted angles. The design of the connection is good as far as the end post and bottom chord is concerned.

Fig.43 shows a common detail used by the American Bridge Company. This approaches the direct riveted connection spoken of in the beginning of this article. This detail is very good in that the end post and bottom chord are rigidly held together by a gusset plate which is riveted to both. This is also good in that the gusset plate and end post extend far enough below the lower chord to make a clear connection for the

pedestal.

A similar detail to this is used as a Northern Pacific Railroad standard. This is shown in Fig.44. The only

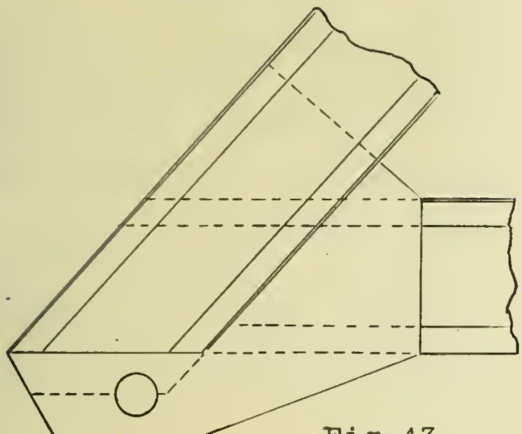

Fig.43.

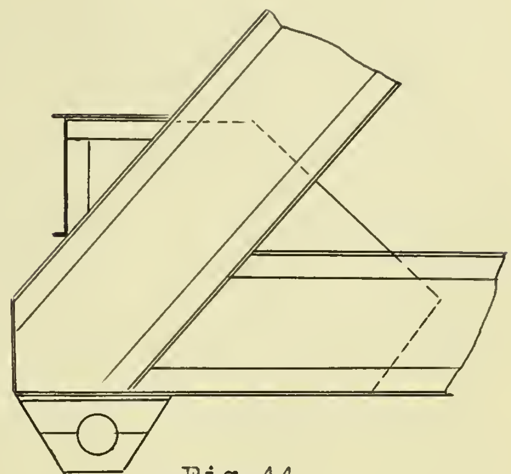

Fig.44.

difference between this and the former detail is that instead of a pedestal connection being made with the gusset plate a separate pedestal connection is riveted and bolted to the intersection of the two. This has an advantage over Fig.43 in appearance if in nothing else. It is also a little simpler in construction but perhaps a little more expensive.

In all the details of the riveted bridges studied, there seemed to be an almost universal use of the gusset-plate connection in preference to the direct connection. Not a single direct-connection detail was found. The probable reason for the plate connection is first, that more rivet area is required than could otherwise be obtained, and second that the gusset-plate connection conformed more nearly to the rest of the design.

In all of the plate connections, the general opinion of bridge companies and designers seems to be in favor of the pedestal being connected below the intersections of the centre of gravities of U_1L_0 and L_0L_1.

In the details shown, those illustrated by Fig.43 and 44 are the most economical and neat in appearance. Fig.41 might be excepted, but outside of these three details all the rest are perhaps to be ranked as possibilities of constructive skill and workmanship. These three might well be chosen as standard details, fulfilling as they do most, if not all, of the requirements in an economical manner.

Art. 4. Top Chord.

The sections of the top chord are without exception of the same general detail as those of the end posts, and as these have been taken up under the end post they will not be discussed here.

Something will be said of the splices in the top chord. The number of these splices depends entirely upon the span of the bridge. For spans up to 100 feet there is usually one splice near the centre. From 100- to 200-foot spans there are three splices. These splices occur near an intermediate post on account of the least bending moment at that point. The splice is used for two purposes, first, because it would be difficult to handle and erect a bridge with long upper chord, and second, on account

of the limit in strength of the member. By having the chord in parts the bridge can be erected in sections. The splice is made by planing the ends of the two posts and placing a plate on one or both sides of the web of the member, and field riveting the member.

The method used for riveting the end post to the top chord is very simple. It consists of planeing the ends of the members to the proper level and then riveting a small plate on the outside and a large gusset plate on the inside. There is considerable latitude in the design of the pin connected bridge, but in the riveted bridge an almost standard detail is employed.

In common practice a detail similar to Fig.45 is used. The end post and top chord are both planed to the same level and riveted up solidly. The same outer plate serves only to hold the two members in line. An extra plate the same size as cover plate is also riveted over the end of the two members. This aids in holding the two members in line and protects joint from the deteriorating influences of the weather.

Sometimes the outside plate is omitted and a detail as shown in Fig.46 is used. Little difference is seen in the general detail. For purpose of erection the field rivets are placed in the end post. The only apparent disadvantage in this detail is the absence of a plate to hold the joints in alignment.

Fig.47 shows another detail almost identical with that of Fig.45 except that there is an irregular-shaped plate riveted on the outside of the two members instead of a plain plate.

No advantage can be claimed for this detail on account of the difficulty which will result in laying out and constructing this plate in the shop. No doubt the appearance isslightly improved but this is hardly worth the extra expense incured. Not with-

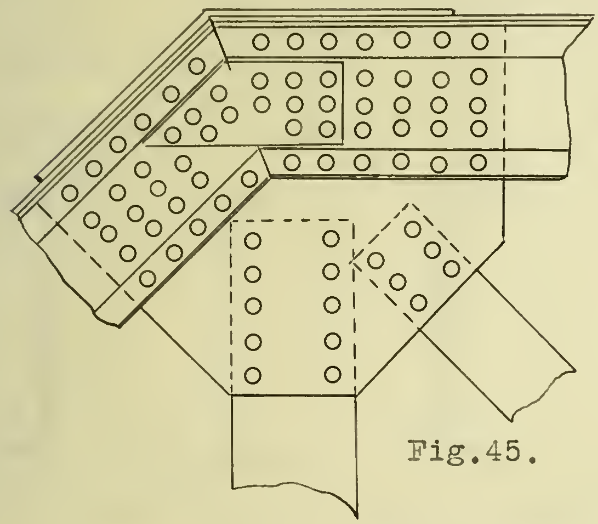

Fig.45.

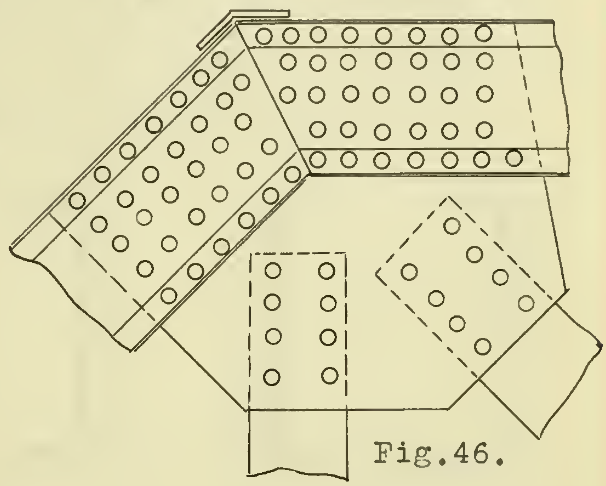

Fig.46.

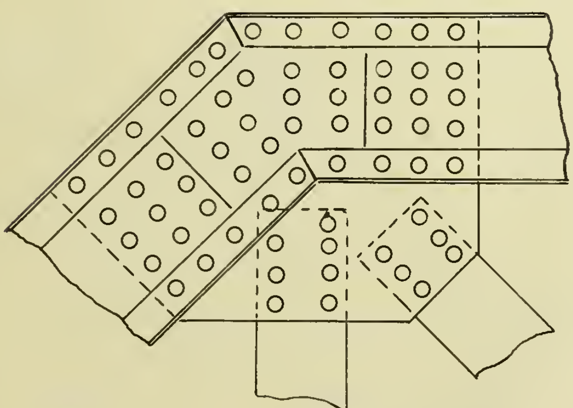

Fig.47.

standing this fact however this form of detail seems to have met favor with a number of bridge companies. The American Bridge Company use only the single large gusset plate on the inside.

On account of the very few different details used for this connection, the selection of a standard detail is a very simple matter. Fig.45 would be the detail chosen.

Art.5. Intermediate Post.

The simplest form of intermediate post consists of two channels held back to back by means of plates or lattice bars. In order to make any kind of connection with the top chord it is necessary to cut the flange away. A better form is to have the flange turned in. Fig.48 and 49 show these two details.

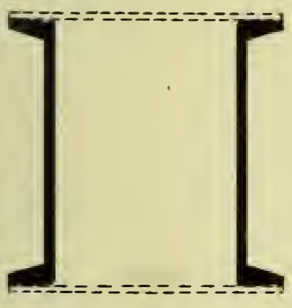

Fig.48.

Fig.49.

Fig.50.

The latter detail is better on account of the additional strength gained by not cutting the flange. The out side measurments can remain the same. The one objection to turning the angles in, is the difficulty found in riveting the lattice bars.

Where greater area is required than can be readily secured by means of two channels alone, a detail shown in Fig.50 is employed. Here an addition to the area is secured by riveting two plates as shown. These plates can be riveted on the inside or outside but the inside is preferable. Where a still larger section is required the post may be built up as shown in the figures below. These figures all show built-up sections used in large bridges. Fig.51 is built up of four angles and lattice bars. As the lattice bars take no stress the only thing to be gained is an increase in the radius of gyration. Fig.52 and 53

are the same details as Fig.48 and 49 except that these are built up. Neither would be used except in large bridges.

Fig.51.

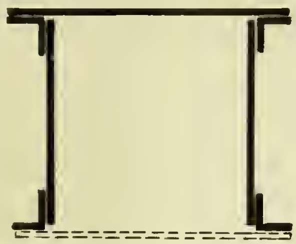

Fig.52.

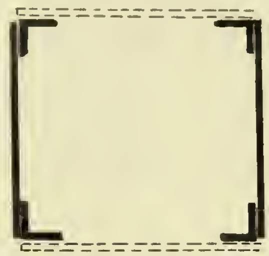

Fig.53.

An unusual detail for intermediate post is shown in Fig.54.

Fig.54.

Fig.55.

This detail was used in the Victoria Jubilee bridge at Montreal. A pair of 20-inch I-beams were used.

A detail used in light railroad bridges is shown in Fig.55. This detail is a popular one on account of the little space the ends occupy at the connection of the top chord and the post. For ordinary spans in riveted railroad bridges the detail shown in Fig.49 and 55 are most commonly used. Both afford an easy means of connection to the top chord and the floor-beam.

There is but one detail for the connection of the intermediate post to the top chord. This consists of making the

width of the post somewhat smaller than the width of the top chord and placing this up inside of the top chord as shown in Fig.56. In the detail shown the intermediate post consists of four angles and lattice bars. The same detail would be used if the intermediate post was made of channels placed as shown in Fig.49. If the flanges were turned out the flange would be cut

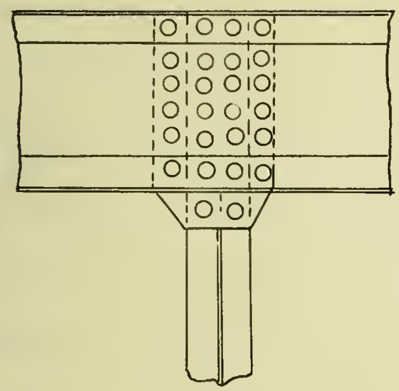

Fig.56.

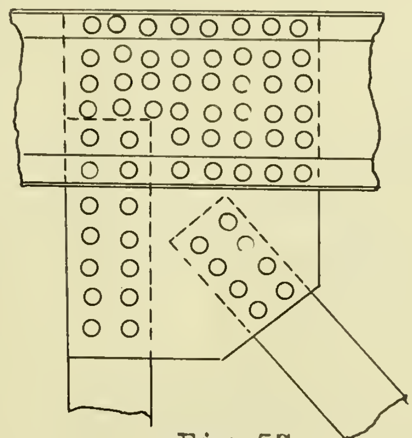

Fig.57.

off, which is bad practice.

If a diagonal intersects the top chord at this point the detail is modified as shown in Fig.57. Where the plate extends as it does below the top chord sufficient rivets can be placed in the intermediate post without extending it up into the post as done in the preceeding example.

The Burnham Bridge on the Maine Central Railroad has a neat connection for the intermediate post to the upper chord. The upper chord consists of a built-up section of four angles and two plates joined by lattice bars. The intermediate post is composed of two channels connected by lattice bars. The connection is shown in Fig.58.

It will be noticed that the gusset plate is inside the channel and that the channels are spaced the same as the upper chord.

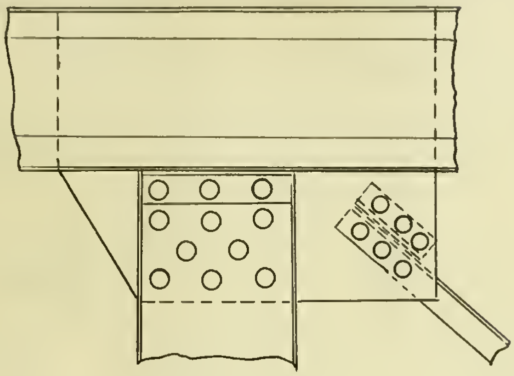

Fig.58.

An angle is riveted to the lower flange of the top chord and web of the channel. This connection affords a bearing surface for the intermediate post and fewer rivets can be used. The detail is good.

What has been said of the intermediate post is true also of the hip vertical. The same sections are used and the same connection made. The hip vertical always takes tension and on account of the magnitude of the stress larger plates must be used. The detail is the same. The ease with which this detail is constructed is a decided argument in favor of the riveted truss.

Art.6. Bottom Chord.

In pin connected bridges it is common practice to make the lower chord of the bridge of eye-bars, but in the riveted truss the lower chord is made of built-up sections.

The most common section used are shown in the sketches below. Fig.59 consists of two pairs of angles held in shape by lattice bars. Fig.60 shows another similar detail made of four angles and plates. This has no advantage over the first except in additional area. All the other forms of box girders used

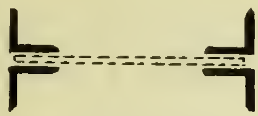

Fig.59.

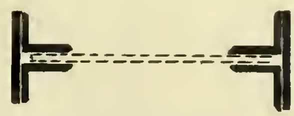

Fig.60.

for top chord and intermediate post section can be used for lower chord in this type of bridge. A light member can usually be used on account of the stress being tension in all cases. The two forms most commonly used are those shown in Fig.50 and the section which consists of two channels and lattice bars. Both of these permit a neat and easy connection for the end and intermediate post.

The detail for the joining of the intermediate post and bottom chord will be considered here. No new difficulties arise, and a detail similar to that employed for the connection of the intermediate post to the top chord is used. A large gusset plate is used in order to give ample room for the connection of intermediate post and diagonals. Where the intermediate post and bottom chord are both made up of channels or similar sections, the lower chord is made large enough for the intermediate post and gusset plate to fit down inside and be riveted. Fig.61 shows this detail. Here the intermediate post is made up of angles and lattice bars and is placed down inside of the bottom

chord. This kind of a detail is neat but in some cases necessitates a wider bottom chord than might otherwise be required. If the intermediate post is composed of channels a similar detail is used.

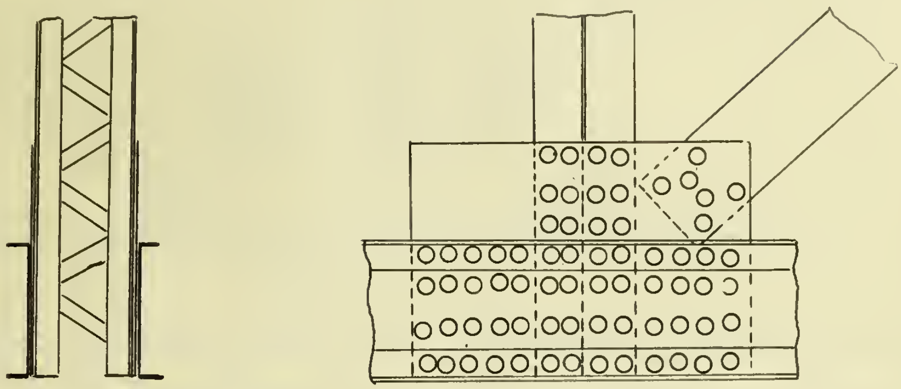

Fig.61.

Sometimes the intermediate post is made up of channels and the bottom chord made up of angles as Fig.58.

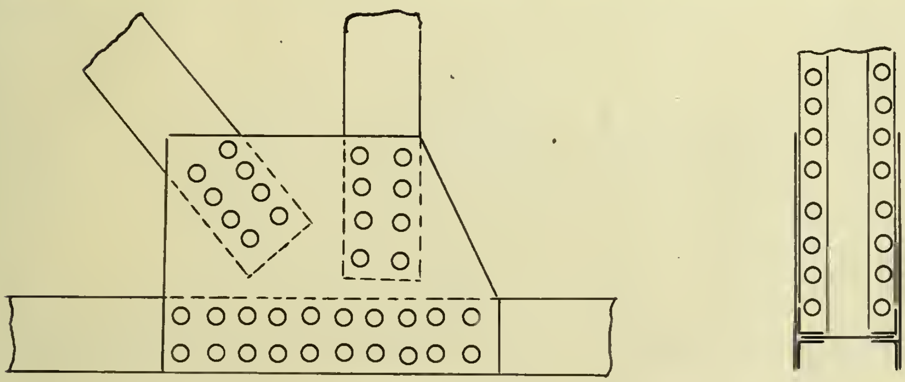

Fig.62.

In this case the detail is shown by Fig.62. The gusset plate is riveted outside of the two members and makes a good connection. The bottom chord can be made small and efficient.

A peculiar design for the connection of the bottom chord to the intermediate post is shown in Fig.63. The detail shown is simple in construction, but lacks in rigidity on account of the lower chord being discontinuous, and it does not seem to

be a popular form of construction for heavy bridges probably on account of the excessively large connection plate required.

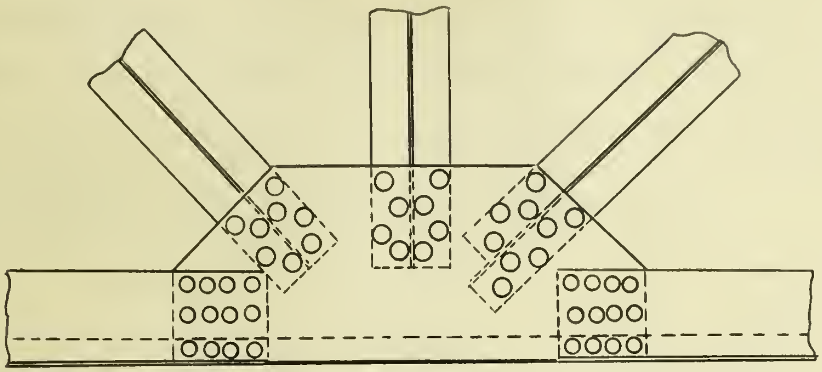

Fig.63.

For a standard detail of this connection the practice seems to be in favor of a continuous lower chord and large gusset plate riveted either on the inside or outside of the lower chord, according to the make-up of its section.

Art. 7. Diagonals.

In order to make a bridge rigid it is necessary to have diagonals in each panel. These diagonals are designed to take tension in some bridges and compression in others. The diagnols near the centre of the bridge are called on to take a reversal of stresses due to the total shear changing from positive to negative or vis-a-versa. To prevent this reversal a counter is placed in the bridge. This counter consists of another diagonal placed in the opposite direction from the main diagnals. In the middle panel and the panels adjacent to it there are usually counters.

The sections used for the counters or diagonals are similar to those used for verticals. The two common forms being the two-channels-and lattice-bars section and the section composed of two pair of angles and lattice bars. Where a heavy diagonal is used no counter is employed because the heavy diagonal can take either tension or compression.

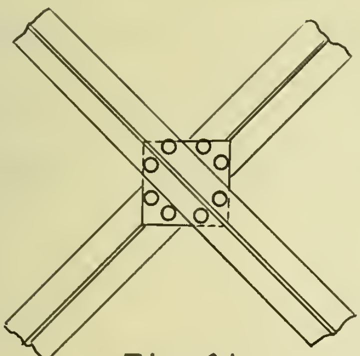

Fig.64.

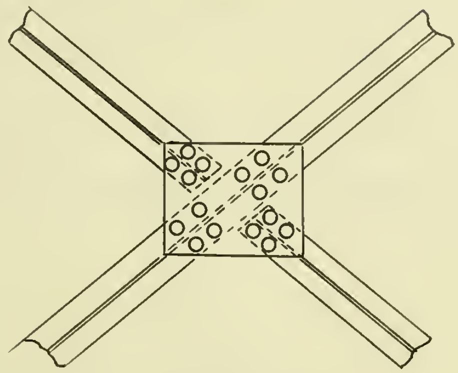

Fig.65.

The method used for fastening the diagonals to the upper and lower chord is simple. It consists of using a large gusset plate connected to the intermediate posts,and to this plate the diagonals are riveted.

There is a little latitude in design where the counter diagonals are used on account of the diagonals crossing. One method for this is in the case shown by Fig.64. Here the diagonals are made up of two angles placed back to back and riveted at intervals along their length. One diagonal is riveted along the outside of the gusset plate on both chords while the other one is riveted on the inside. At their intersection they are riveted to each other. Sometimes directly and sometimes by putting a small plate between the two pairs of angles. It is preferable to

have this small plate in order to keep the counters straight.

Another common form of intersection is shown by Fig.65. A large plate is used at the intersection and the counter diagonal is broken. By this method of intersection large diagonals can be crossed and much neater details secured at the upper and lower chord points. This detail is the better of the two methods used, and can be used with any kind of cross section. There is an objection to this detail in the size of the plate used. A somewhat neater but perhaps no more effective detail is that shown in Fig.66. The plate used in the connection instead of being a

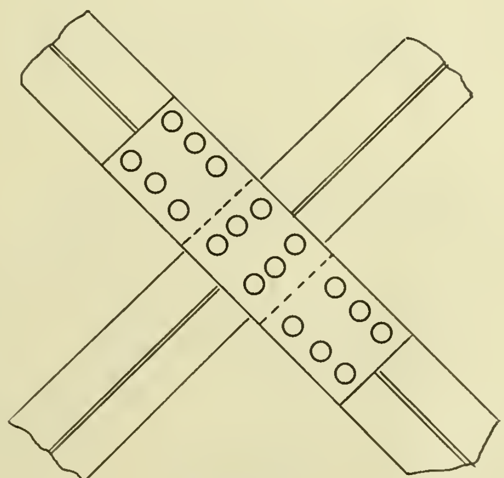

Fig.66.

large square plate is simply a plate the same width as the member itself. This method works equally well for box sections as for the particular detail shown which consists of two pairs of angles and lattice bars. There is little doubt but that this detail is the best of any detail shown for the intersection of two diagonals. It is neat and effective, easy to put together, and rigid. There is no trouble in getting enough room for rivets as the length of the plate can be varied to suit.

Art.8. Portal and Sway Bracing.

Most of the details shown in the preceeding pages are more or less uniform, but the details of the portal and sway bracing are far from uniform. In fact duplicate portals are rare inasmuch as the entire detail rests with the designer.

The fastening of the two trusses together by means of a portal and sway bracing is an important detail. In the end post this detail is especially difficult on account of the inclination of that member. It is always desirable to fasten the portal to the posts near if not at the centre of the side. To accomplish this the connection is as shown in Fig.67. This can not always

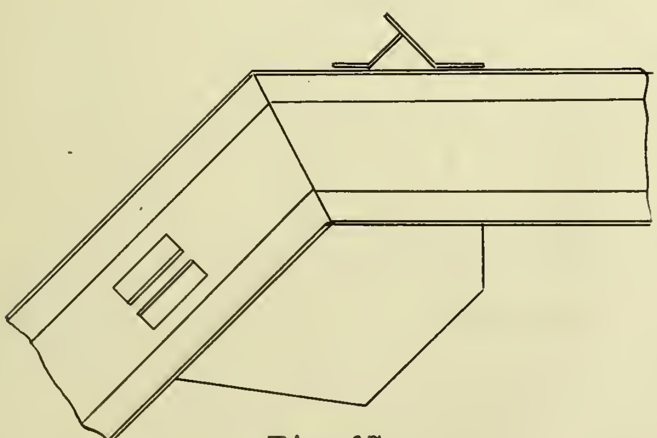

Fig.67.

be accomplished and the portal is sometimes riveted to the end post by plates on the upper side of the post. This is objectionable on account of the twisting moment which is caused in the post. Sometimes the portal is connected only along the length of the post and not fastened to the upper chord as shown in Fig.68. For very heavy bridges the portal is sometimes built as deep as

the end post and is riveted to it by plates on both sides of the post. This is a very good method as the entire stress is evenly transmitted to the end post. This method can only be used economically in large bridges, on account of the large size of the members required for connection.

The problem of fastening the intermediate post and sway bracing is easier than that of the portal. The systems themselves are similar to the portal but on account of the position of the intermediate post and top chord a connection can aesily be made. There is no reason why the sway bracing can not be fastened at the middle of the post and this is commonly done. To accomplish this a pair of angles is usually riveted to the intermediate post. If it is possible to have a heavy sway-brace the sway bracing may be riveted by means of plates on both sides of the intermediate post. The connection is never made by an angle on one side alone.

On account of the great number of different types that can be employed, only a few of the general types will be considered here. It is always desirous to have an attractive portal for it is by the portal that most people judge a bridge. Besides being an object of beauty, this portal must hold the bridge perfectly rigid.

Portals and sway bracing may consist of angles or plates, or both. In the smaller bridges it is always desired to have plenty of head room, and to accomplish this it is necessary to supliment the portal bracing by knee braces in order to give sufficient rigidity to the bridge in a plain perpendicular to

the trusses.

No doubt the most common form of bracing in the portal is the angle. There are many types, two forms of which are shown in Fig.68 and 69. Fig.68 is the simpler but is no more effective than Fig.69. The detailing is simple and both are fastened to the end post by angles and plates.

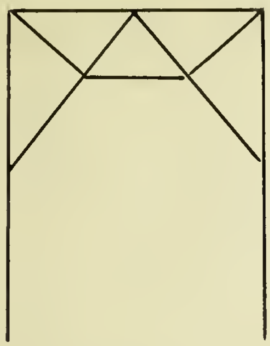

Fig.68.

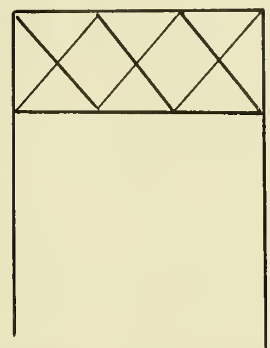

Fig.69.

In rare cases plates, reinforced by angles, are used as portals. Fig.70 shows a case of this kind. Fig.71 shows a

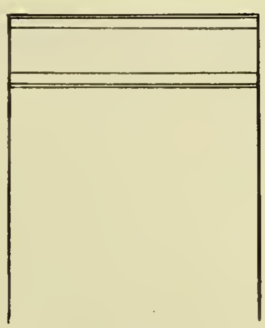

Fig.70.

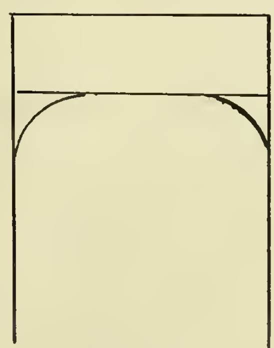

Fig.71.

similar detail. The only difference being in the bracing. This detail altho more difficult to make is by far the neater and better detail of the two. A neat and simple detail for a portal is shown in Fig.72. This detail consists of lattice angles and plate bracing. A somewhat similar detail for a portal is shown

in Fig.73. This detail is one made by a Canadian bridge company.

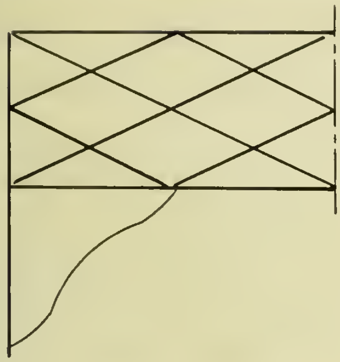

Fig.72.

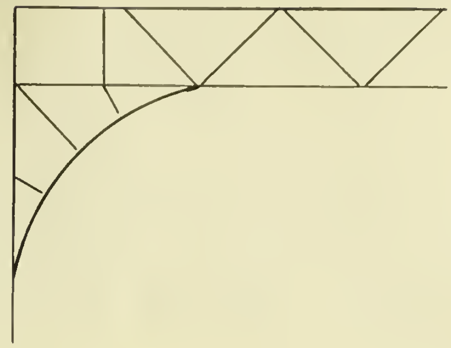

Fig.73.

It has some points of beauty but is not a common detail on account of the difficulty in building. Instead of a plate used as a brace an angle is bent and rivetedto the end strut and end post. In order to make this effective as a brace it is necessary to place short braces as shown.

The portal of Fig.74 is much better practice, but not quite as neat in appearance. This is very easily built since it consists of angles and plates only and is to be recommended as a good detail. Another similar in appearance is shown in Fig.75,

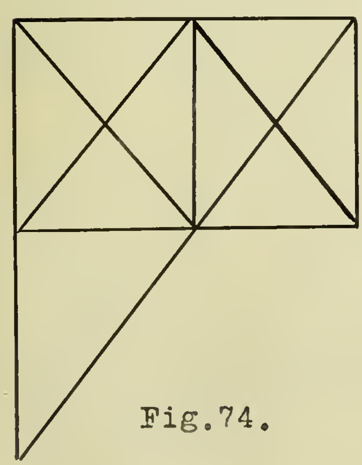

Fig.74.

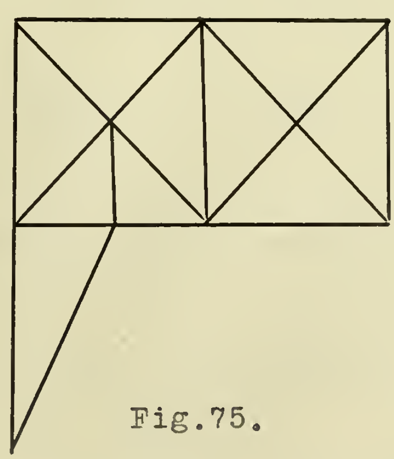

Fig.75.

and is a very good detail. This detail may or may not have a

gusset plate as a brace. For very heavy bridges the portals are usually made of plates and, as mentioned in the first part of this discussion, are usually as deep as the end post in order to be fastened to both of it's sides.

A standard portal used on the Northern Pacific Railroad is shown in Fig.76 This detail is a neat and effective detail but certainly requires work and skill in the shop. Outside of

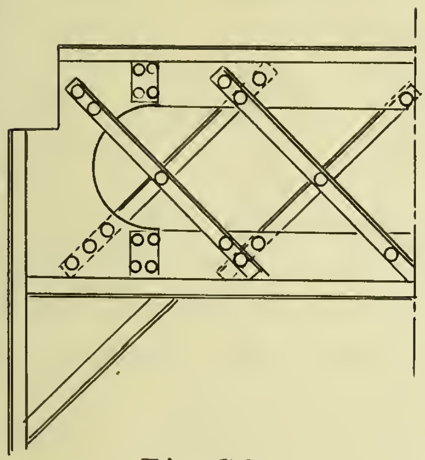

Fig.76.

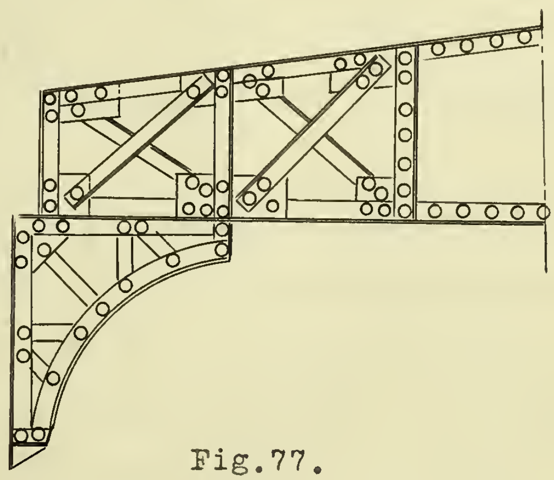

Fig.77.

the end plates in which the end circle is cut, the work is easy and the design economical. There is no advantage gained in the shape of this end plate.

A portal used by the Baltimore and Ohio Railroad is shown in Fig.77. This detail with the exception of the brace is very good. The increased depth at centre makes it possible for the portal to take more bending stress. A straight knee brace is more effective than the brace shown, and is much easier put in place.

Some of the largest bridges have comparatively simple portals, some of the general shapes of which are shown below:-

Fig.78. Railroad bridge at Rock Island. Fig.79. Delaware River bridge at Philadelphia Union Railroad Bridge. Fig.80. Rankin Pensylvania.

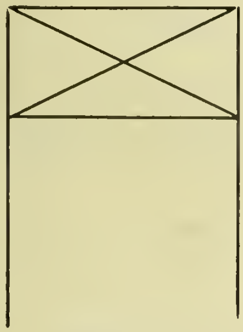

Fig.78.

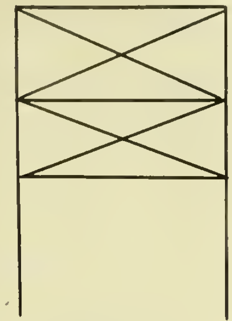

Fig.79.

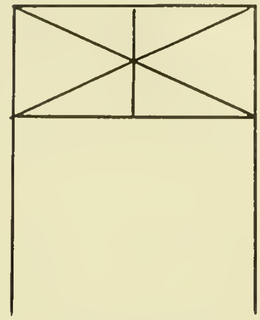

Fig.80.

The details of the sway bracings in all bridges are similar to that of the portals. In fact the same designs are used in most cases. The sway bracing is usually lighter, and may be of less beauty on account of their position. The first requisite in both the portal-and sway-bracing is rigity. It is desirable to have the portal extend as far down the end post as possible and still give sufficient head room. In high bridges it is simple enough but in ordinary bridges the knee brace has to be employed in order to give necessary rigidity.

Art.9. Lateral Systems.

There is but one system of lateral bracing used, and that is to have two diagonals in each panel. It was the practice some years ago to have round or square rods with turn-buckle adjustments, for the lateral system in a manner much the same as

that now in vogue in the construction of highway bridges. At the present time this practice has been almost discontinued, and specifications call for stiff members. The only argument for adjustible bracing is the lightness and ease with which the two trusses can be lined up. With the stiff laterals the bridge is held rigidly and when once in adjustment it is always in adjustment.

Only the stiff laterals and their connections will be taken up here. There are two systems of laterals, the upper and lower system. The most common form of lateral is that of a single angle. Sometimes in order to give greater stiffness two angles are used placed back to back. For heavy bridges where the laterals need to be stronger, two pairs of angles are laced together. In a few instances the laterals are composed of two angles laced together.

It remains to discuss the method of connecting these laterals to the upper and lower chords and the intersection. In the upper system where the single angle is used two different methods are employed. One method, altho not a common one, is to rivet the angles directly to the top of the upper chord either by one leg or both. Another method is to rivet a plate on the top of the upper chord and extend it some distance over the edge of the chord. By this method ample room is given for riveting and a place for the lateral strut to be fastened. In case two pairs of angles are fastened together by lattice bars, the lateral is usually made as deep as the upper chord and fastened to it by means of a plate on both it's top and bottom.

A no more difficult problem is found in the details of the lower lateral system. The floor system usually is made so that the bottom of the floor-beam comes on a level with the bottom of the lower chord. When this is the case a large gusset plate riveted to the bottom of each affords a place for the connection of the bottom laterals. The bottom lateral usually consists of the angles only, rather than the lattice laterals. Where it is possible for the bottom of the stringers to be placed as low or nearly as low as the plain of the bottom laterals the laterals are riveted to the stringers.

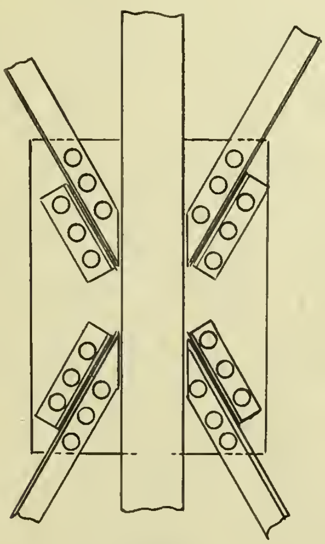

Fig.81.

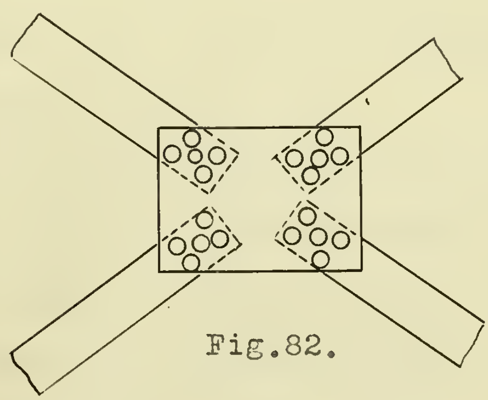

Fig.82.

A method sometimes used in double track bridges where the panels are short is to run the laterals as shown in Fig.81. The laterals themselves being single angles. The details of the intersection of the laterals is the same as used for the diagonals. An additional detail is shown by Fig.82. This detail is

used for both angles and plates, but no advantage can be claimed over that in which one of the angles or plates is unbroken.

Art.10. Bearings.

The last problem which confronts a bridge designer is that of the pedestal and bearings. There have been many solutions offered but none seem to be just what is wanted. For bridges of spans up to 75 or 80 feet a base plate is fastened to tne end of the bridge and bolted to the abutment. One end is bolted solid and the other is allowed to slide on a smooth plane. This plate is held in line however by a stone bolt passed through the slot in the plate. These slots allow for any movement due to the contraction or expansion of the truss.

For bridges of over 85-foot span the bearing plate rests on rollers. These rollers are made of hardened steel and are held in place by a frame. The diameters of the rollers vary from 3 to 5 inches. The larger the rollers the better, for a small roller is easily clogged up by dirt and rust.

In all types of bridges the bearing plate and pedestal are connected to the truss by means of pins in order to allow for any sagging. These pins vary from 4 to 6 inches in diameter. The pedestal may be made of angles and plates or cast steel. The former is the most common. Fig.83 shows a type of built up pedestal with rollers. The rollers should be incased in a box in order to keep out the dirt.

Fig.84 shows a cast steel pedestal. The only advantage of the cast steel over the built up pedestal is that in the cast pedestal the pin in the rocker transfers the load over the larger bearing surface than can be done in the built up pedestal.

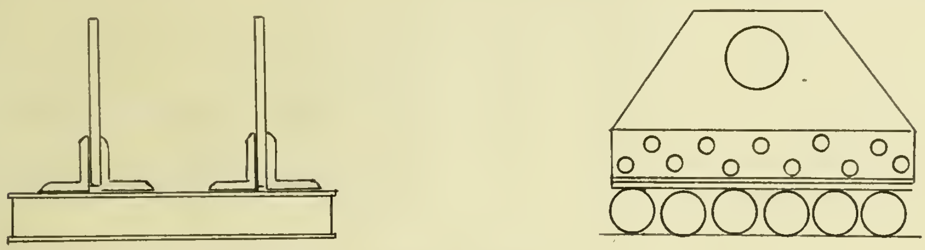

Fig.83.

As only one end of the bridge is on rollers some provision for the other end must be made in order to avoid using different heights of supports. A common way to do this is to

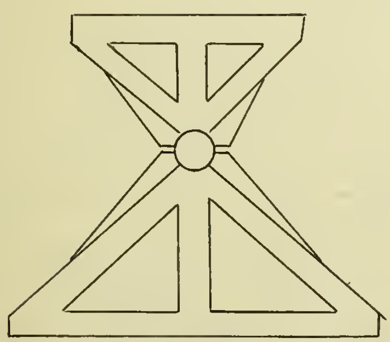

Fig.84.

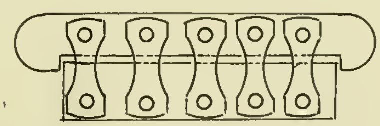

Fig.85.

Fig.86.

place a base plate at the fixed end in place of rollers. Sometimes a number of channels or I-beams are placed side by side to take the position of rollers on the fixed end.

In very heavy bridges the rollers as employed in small bridges would cover a much larger area than that usually allowed

for the bridge seat. To avoid this a set of rollers shown in Fig.85 are used. By this system of rollers the bearing surface for the rollers is the same as for cylinderical rollers but the bearing surface on the masonry is reduced. The dimentions of these rollers are from 8 to 10 inches in height;and the rollers allow considerable movement of the bridge. Instead of resting on a plate these rollers very often rest on a surface made up of rails as shown in Fig.86.

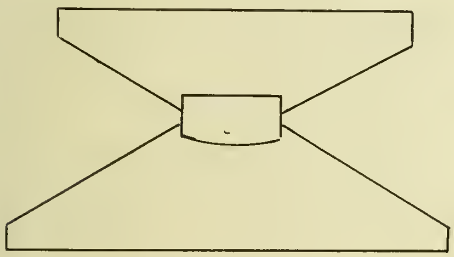

Fig.87.

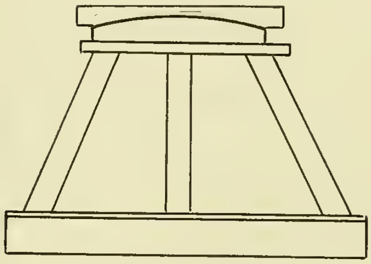

Fig.88.

In heavy bridges sometimes a pivot joint is made instead of a pin connection for the joining of the two parts of the pedestal. This is shown in Fig.87. This form is known as a rocker plate. The advantage of this detail is that the rocker plate makes it possible for the bridge to adjust itself as it is being erected and there is no doubt but that an even bearing surface is always had.

A similar detail to this is used by the Montreal Bridge Company on a Canadian Pacific Railroad bridge. Fig.88 shows a sketch of this detail. This detail has the same advantage as the one mentioned above. The disc used in this particilar detail is made of cast steel polished, and is 15 inches in diameter.

The detail for the pedestals themselves vary so widely that an attempt will be made to give only a few.

Sometimes the stress is transfered from the bridge to the rollers usually through two webs, but sometimes as high as four or five are used, the number depending on the size of the bridge.

The built-up pedestals seem to be most used in ordinary bridges, on account of the saving in weight principaly. No rule can be laid down for the best pedestal and bearing for each class has its faults. Rollers become rusted and flat on their sides, but as no better means can be devised to allow for the longitudinal movement nothing remains but to use what we now have.

Conclusion.

After a study and comparison of the plans from the Montreal Bridge Works, American Bridge Company, Chicago Steel and Iron Works, Phoenix Bridge Company, King Bridg Company, Pennsylvania Bridge Company, and Boston Bridge Company as well as standard plans given in technical journals, the author has realized that a vast number of details are possible. It is very unfortunate that these various details could not be standardized in order to simplify design.

An attempt will be made in this conclusion to collect

representative examples, the best of their class, that might be selected for standards.

STRINGERS. Very little latitude for variety of design is possible in this detail. A single plate girder stringer is to be preferred over two I-beams. The detail shown in Fig.1 is perhaps the best form.

FLOOR BEAMS. Of the many different deaigns for Floor beams the best type of end floor beam is that used by the American Bridge Company and is shown in Fig.14. As an example of standard intermediate floor beam, a detail given by both the American Bridge Company and Boston Bridge Company is the best. Fig.22 shows this detail. Both of these are to be recommended on account of the simplicity of design as well as ease of construction.

END POST. For the end post the best practice recommends a built-up section, or two channels single laced, according to the size of the bridge. There is little doubt but that the connection of end post to bottom chord should consist of a large gusset plate riveted inside the channels. The end post should extend to bottom of lower chord. Fig.42 shows this detail.

TOP CHORD. The section recommended for top chord is the same as that for the end post. For a top-chord and end-post connection the detail shown in Fig.44 is the best on account of it's rigidity.

INTERMEDIATE POST. In riveted bridges the best form of intermediate post is the one built up of angles and plates

or two channels and lacing. In both cases the legs should be turned in. This gives a better chance to make the floor-beam connection. Fig.48 and 52 show these details. Two pairs of angles connected by lattice work should be used only in light bridges. Fig.56 is recommended for the connection to the top chord.

BOTTOM CHORD. Sections similar to those used for the top chord and end post, but of lighter construction are recommended for use in the bottom chord. The detail which is the best connection for the bottom chord and intermediate post is shown in Fig.60.

DIAGONALS. The best type of diagonal for a riveted bridge is one composed of two pairs of angles connected by lacing. This kind of diagonal is easily connected and is perfectly rigid. Where two diagonals intersect a plate as wide as the member should be used to transfer the stress across the intersection.

PORTAL & SWAY BRACING. In this detail a wide variety of details can be chosen. Beuty of design has much to do with the particular form to be decided upon, and it is well to keep this in mind. A very good and simple portal is shown in Fig.69, which meets the favor of many bridge designers. It is equally suited for light or heavy bridges. It gives both a good brace and a high clearance. For heavy bridges the portal can be made as deep as the thickness of the end post.

LATERAL SYSTEM. The lateral systems should be such that the bridge is held rigid. The only detail which

accomplishes this, and keeps the ratio of length to radius of gyration less than 120, is the two angles laced or two pair of angles laced. For riveted bridges either will do and both can be recommended. For the lower system a pair of angles or even a single angle is enough on account of the laterals being connected to the bottom of the stringers thus reducing the length of the members.

BEARINGS. Of the details for bearings discussed, there is little doubt but that a built-up pedestal is preferable to one of cast steel. Large rollers are to be used. For heavy bridges the type of roller shown in Fig.85 is recommended on account of the saving which results in the size of the bearing and masonry plates.

These few representative details are the ones that appear to have the most points in their favor, and altho they may not be universally selected by engineers as their standards, yet it is thought that they represent for the greater part, the best practice. The American Bridge Company have more nearly standardized their details than any other of the bridge companies whose plans were studied.